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Application of Two Rendering Techniques in the Visualization of 3D Geospatial Data

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Abstract

Geo-scientific engineering is an ongoing project to obtain data, analyze data and process data, especially in the geological engineering investigation, design and construction process. We aimed to quick process and timely feedback of all kinds of unexpected data and information to guide the construction. Visualization technology is used to effectively and intuitively process and synthesize data. The dataflow model of 3D visualization process is described, and the visualization technologies are introduced to construct the geo-objects from 3D geospatial data. The applications of 3D visualization technologies to the analysis and processing of geological engineering data will improve the management and utilization of various geological engineering data for the engineering staff, and will promote the geo-scientific work effectively towards the direction of digitalization and visualization.

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1. Introduction

Three-dimensional (3D) visualization and construction of geospatial data is one of the most active frontiers in the field of geo-science; meanwhile, the geo-scientific industries have long waited for an effective system that highly integrates geo-modeling, visualization and information management into a true 3D environment. Computerized 3D reconstruction and modeling of geospatial data involves the handling, analysis, visualization and interaction of large data sets [1-3].

This paper presents the applications of 3D visualization and construction to the integration of large scale geospatial data sets that are common to the geo-scientific environment. The research arose from a recognized need to integrate large and disparate data sets and improve methods for the construction of

geo-models so that their interpretation and transfer between disciplines can be optimized and utilized. The paper introduces the data types and features of geospatial data. Then, the basic processes of 3D visualization of spatial data fields and two different visualization analysis algorithms are discussed.

2. Geospatial data types

The data observed vary as the application fields of visualization technology are different. The data come from scientific experiments, computer simulation, production practice, and instrument measurement. The data formats and characteristics are diverse and all-inclusive. The most common is scanned through a variety of scientific instruments, such as magnetic resonance imaging (MRI), computed tomography (CT) and so on. Among engineering applications, often using finite element analysis and computational fluid dynamics method produces a variety of analog data. Meteorological, geological exploration data are largely obtained through observations. These data are one-dimensional, two-dimensional, three-dimensional, four-dimensional, and even higher dimension. Current research on the three-dimensional data field is the most active.

Three-dimensional data field visualization algorithms and data types of the observed great relationship. For different data types, there are corresponding different visualization methods. Here's the data type has two meanings, first, the physical type of the data itself, and second, the relationship between the data distribution and connection type, or data space organization. The data fields are discussed and the form of spatial organization of the physical characteristics of the data according to the classification.

2.1 Organization of geospatial data

In scientific computation, the characteristics of the research objects are often described by a set of equations [4]. They are usually ordinary differential equations, partial differential equations, and integral equations, linear or nonlinear equations. If you can find the analytical solutions of these equations, then these equations can be defined anywhere within the space needed to get the solution. However, only when the equation is relatively simple, it can be solved. In general, we can only find the numerical solution of these equations. To this end, the space needs to be defined by discrete, discrete adult cell, surface unit, line or grid point, and then find the numerical solution of these discrete units office function value. Therefore, scientific data is often the result of discrete, not continuous.

As for space measurements, such as geological exploration data, meteorological monitoring data, the human body CT scan or MRI data, usually discrete. The reason is that it is hard to achieve continuous in space measurement data, therefore, visualization of the object generally refers to three-dimensional space of discrete data, that volume data.

Volume data can be divided into structured volume data and unstructured volume data. The volume data for structured sampling point exists between the various dimensions of the adjacency relationships determined and unified, it's any one sampling point all OK with it in the rows, columns, layers of the serial number to represent. According to the structure of volume data in the physical distribution of the different elements, and can be divided into the following categories [5].

1) *Uniform structured grid volume data*. It is also known as Cartesian type data, which is based on three-dimensional Cartesian grid data field, each element is the same size, arranged according to the coordinate axes are cubic block. Node coordinates can be expressed as (i, j, k) , where i, j, k for the node number. The two-dimensional diagram is shown in Fig. 1 (a).

2) *Structured regular grid volume data*. All elements are the same size, arranged according to the long axis direction of the box. Node coordinates can be expressed as $(i \, dx, j \, dy, k \, dz)$, where dx, dy, dz is a constant. The two-dimensional diagram is shown in Fig. 1 (b).

3) *Rectangular structured grid volume data*. Along each coordinate axis, the spacing between grid points are not equal. Elements are still arranged along the long axis box. Node coordinates can be expressed as $(x[i], y[j], z[k])$, where $x[i]$, $y[j]$ and $z[k]$ is an array. The two-dimensional diagram is shown in Fig. 1 (c).

4) *Irregular structured grid volume data*. It is also known as curvilinear data. Each element is a logical hexahedral, relatively parallel to the surface does not require, and each side of the four vertices cannot coplanar. The entire data field is three-dimensional space from the Cartesian grid to a map. Typically have three-dimensional finite element mesh, such as fluid dynamics grid, node coordinates can be expressed as $(x[i, j, k], y[i, j, k], z[i, j, k])$. The two-dimensional diagram is in Fig. 1 (d).

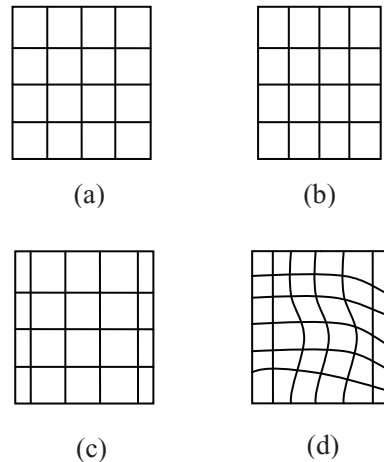


Fig. 1. Different kinds of structured geospatial data

With the above data types, unstructured volume data is formed by a series of units, these units can be tetrahedral, hexahedral, prism, or prism, etc. 4. In some applications it is sometimes necessary to structured data and unstructured data, used in combination to form a hybrid data types, so that the data that is more convenient and also less computational requirements.

2.2 Classification according to physical characteristics

The physical characteristics of the data, the data field can be divided into scalar and vector fields. Scalar field is only the size of the data without the direction of the data field. More common are the density field, temperature field. Scalar field visualization is to reveal the main spatial distribution of all classified material. Vector field values not only the size of the data, as well as the direction of change. Typical data fields are fluid. Vector field visualization in addition to revealing the spatial distribution of various categories of material, but also reflect the changing trends.

3. Visualization data flow of 3D geospatial data

Although different types of spatial data, data distribution and connection of differ greatly, but the visualization process is essentially the same. Fig. 2 expressed three-dimensional data field visualization of several major steps.

3.1 Data preprocessing

Mainly to filter the raw data, spatial data has been found to eliminate or gross errors may occur, and make the necessary changes, adjustments, added a number of markings. Data too large for the original data need to be refined and screened in order to appropriately reduce the amount of data, improving the rendering speed; the contrary, when the data distribution too sparse, which may affect the visualization, you need effective interpolation encryption process. The ultimate goal of data preprocessing is to be more interested in research, and to reflect the actual situation of the standardization body of data.

3.2 Data mapping

The main geometric primitive extraction and construction of visual models, so that data with an appropriate range of graphics or image display, will have normalization of the data mapped to the display properties of the geometry factor. Commonly known as 0-dimensional geometric point of map elements (e.g. particles), one-dimensional line graph elements (such as contour lines and flow lines), 2-dimensional surface map elements (such as iso-surface, surface flow, etc.), 3D body and higher-dimensional pixel-based features such as icons pixels.

3.3 Rendering and display

The geometry of the data elements of expression, giving the visual characteristics of geometry factors (such as color, transparency, texture, shadow, etc.), which is the core of the visualization process. Sophisticated computer graphics theory and methods provide a wealth of rendering algorithms available, including scan conversion, as the view transformation, hidden surface removal, lighting calculation, shading treatment, transparency and shadows, texture mapping and anti-aliasing technology, and so eventually the geometric elements and attributes into graphics or images for display, and in the form of static or animated display.

3.4 Graphical analysis and feedback

Visualization purpose is to give people rich visual "information", not just giving a rough "image" [6]. Researchers do not know in advance which parts of the original data set on the analysis of the most important and cannot be pre-determined data set to the geometric elements of the best mapping and map out what the optical properties of the image best. These have to rely on continuous practice of groping. Thus, the visual analysis process is a repeated cycle of iterative refinement process [7].

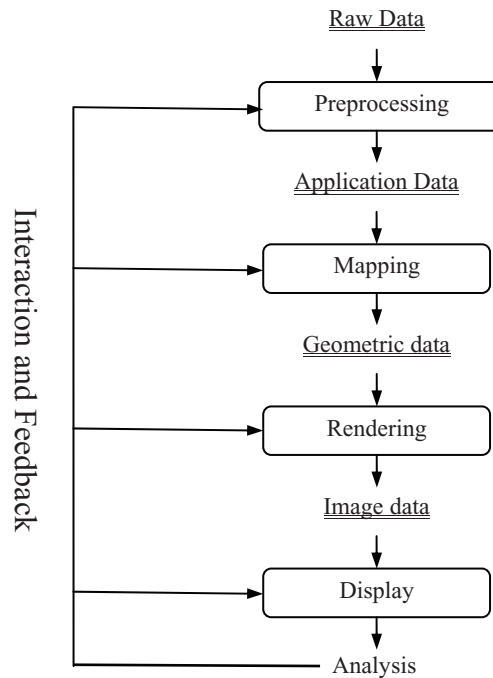


Fig. 2. Visualization dataflow of 3D geospatial data

4. 3D data visualization algorithms

The purpose of visualization is to explore the internal data field contains the physical laws and geometric properties, therefore, for the same data sets are often many different visualization methods. Through a variety of ways to visualize the same data fields also help to overcome the single visual defects arising from the method, allowing a more comprehensive field of data visualization of various attributes. The distribution of the data field in three-dimensional space, the resulting image according to its visual expression of different, can be divided into two different types of visualization methods, surface rendering and volume rendering.

4.1 Surface rendering

Surface rendering method (also known as feature extraction method) the first three-dimensional data field extracted from the middle of geometric factors (such as curves, surfaces, etc.), and surface maps for the visualization of data element attribute value, then the traditional computer graphics technology to draw the screen. Therefore, this method is mainly based on surface modeling technology and graphics technology in the illumination model reconstructed from the data field in three-dimensional objects, and its realization method can be divided into two types: one is based on the contour lines of the surface reconstruction (Reconstruction from planar contours), the first in a series of two-dimension surface contour generation, and then connect into the equivalent of these contour surfaces [8]; Another solution is to not generate the contour surface of two Dimensional Instead, the data field directly in the body of each

voxel within the extracted iso-surface, and the equivalent surface area to connect into the equivalent, known as voxel-based reconstruction methods [9].

4.2 Volume rendering

Surface rendering graphics based on the traditional method of three-dimensional modeling of the formation of three-dimensional shape data field, will be projected onto three-dimensional shapes on two-dimensional plane, mainly through the shape of the depth of information, generate three-dimensional sense. This graphic is only the surface expression of the effect of three-dimensional physical space, and three-dimensional data field does not reveal the variation within. Although other software can be like slicing technology, profiles and technology to observe the variation within the data field, but it reflects the amount of information is limited. Volume rendering algorithm is to overcome this limitation and developed a new generation of visualization technology, which is characterized by three-dimensional data field as a whole shows that it's different levels, materials, characteristics of the various components shown in an image obtained is the global three-dimensional image data field, data field within the fine structure and small changes can be manifested in varying degrees [10]. Its visual technology with the traditional main difference is: it is not through the middle of geometric modeling and other means of conversion, that is, it's dealing with are no longer the curve, surfaces and other geometric primitives, but directly to a standard amount of three-dimensional field or vector field operation, which direct to the data field in the volume element given a certain color and transparency, and when under the light through the translucent material and energy gathering the optical principle of operation of the color image synthesis.

5. Create 3D geo-models

Visualization applications have used different requirements rendering: real-time rendering for interactive visualization applications need a different rendering technology as high quality picture productions to use for computer-generated videos. While it is possible to estimate the overall geometry of the geological and mining objects from sparse data sets, even if not to make any additional data such as drill core, orthographic images or mine workings exist, it is limited to general guidance in the modeling. In fact, it is natural for a structural geologist to mentally visualize geometric solutions for a limited amount of data, and articulate these solutions as regional cross-sections or block diagrams. As additional information becomes available, these models tend to be a unique solution. Integral to the structural modeling of the exercise of sketching, to expand engineering and surface properties is deep [11].

With sufficient data density, standard interpolation techniques available to the surface models required to create a specific geological structure visible. These methods are used to calculate an optimized close fit of control data by iteratively minimizing the error between the various checkpoints and the cells of the modeled surface. As a consequence, the disturbed areas are difficult to manipulate in a computer. They require more advanced algorithms that can cope with rapid changes in slope, or sharp discontinuities. These types of surfaces can be the location of the tension of the interpolation model to highly variable regions. This includes the reduction of the allowed local error in discontinuities and relaxing it is less variable, but sparse regions [12]. The reconstructions of 3D models from geospatial data are shown in Fig. 3 and Fig. 4.

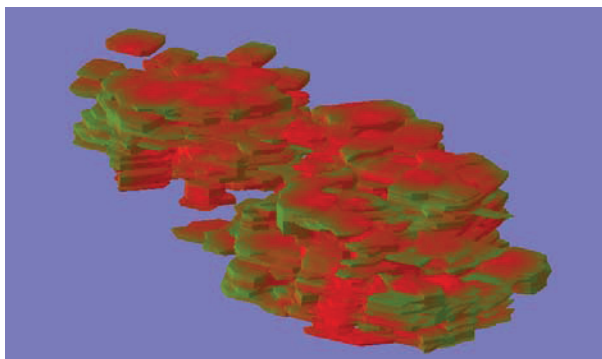


Fig. 3. Construction of 3D geo-model

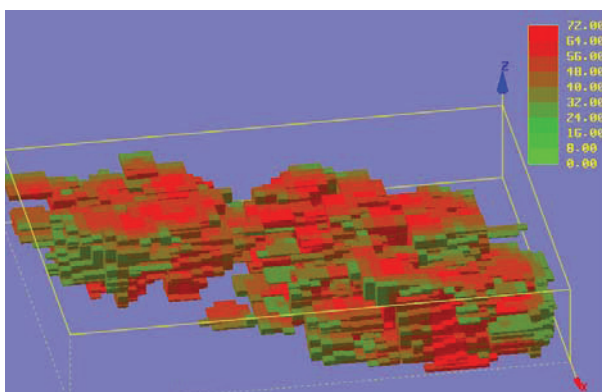


Fig. 4. 3D visualization of geospatial data

6. Conclusions

A wide variety of visualization techniques have been developed to support geospatial data visualization and exploration. Some have evolved from early manual method to more recent digital methods. For example, various projections of 3D orientation data on lower hemisphere plots, 3D block diagrams, structural contouring techniques, and more recently integrated GIS products such as structurally symbolized image maps. All of these are designed to enhance the interpretive environment so decisions can be made in a more rigorously constrained manner. In this paper, the purposes of the establishment of 3D geo-models are not just the displaying of the models. What is more important is to establish the appearance and the internals of the geo-bodies. The characteristics of geospatial data for the general visualization algorithms have been applied to construct geo-bodies. The dataflow model of visualization process is described, and two visualization techniques are introduced to construct the complex geo-bodies.

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